Gaza's Water and Sanitation Crisis: The Implications for Public Health

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In July 2017, a five-year-old boy died in the Gaza Strip after swimming in seawater polluted with sewage. Dozens of others have reportedly been treated after swimming in Gaza's seawater over the summer months of July and August.[1] Receiving international media coverage, this story has put the spotlight on a problem long in the making: Gaza's chronic water and sanitation problems pose immediate serious risks to public health.

Gaza's water issue is twofold: a shortage of potable water combined with a lack of wastewater sanitation. The first part of this problem is the lack of access to plentiful safe water for drinking, cooking, and bathing, which puts Gaza's population in peril. In addition, over 108,000 cubic meters of untreated sewage flow daily from Gaza into the Mediterranean Sea,[2] creating extreme health security risks in Gaza as well neighboring Israel and Egypt. While these problems are not new, rapidly deteriorating infrastructure, strict limitations on the import of construction materials and water pumps, and a diminished, declining, and unreliable energy supply have in recent years expedited the water crisis and exacerbated the water-related health risks.

This article examines the implications of Gaza's water crisis for public health. The Strip's water problems are inseparable from its energy woes; this linkage is addressed in greater detail elsewhere in this collection. The article first reviews the general factors that have worsened Gaza's water crisis recently; this is followed by an overview of the current domestic water supply and state of water sanitation in Gaza. It then describes water-related risks to public health, particularly chemical and biological contamination, and explores the health risks that Gaza's water problems could pose for Israel and Egypt. Finally, the article suggests immediate steps that can be taken,

even under current political constraints, to mitigate the water and sanitation crisis and reduce the likelihood of a significant public health disaster.

Factors Exacerbating the Water and Sanitation Crisis

Even though the water and sanitation crisis in not a new phenomenon in Gaza – the Strip could be described as in a chronic state of water emergency – a confluence of negative developments has exacerbated the situation and raised the associated health risks. First is the continued depletion of the coastal aquifer, Gaza's only source of freshwater, which is not sufficient to meet the needs of the 2 million Palestinians living there. Decades of over-pumping, combined with intrusion of wastewater, agrochemicals, and saline water, have brought the aquifer to a state of possibly irreparable damage.[3] Over 96 percent of the aquifer is already unfit for human consumption.[4]

Moreover, recurring conflict with Israel has severely damaged the water, sanitation, and hygiene (WASH) infrastructure in Gaza. A Palestinian official report assessed the damage of Operation Protective Edge (2014) to WASH infrastructure at $34 million. This includes damage to groundwater wells, the water reservoir, wastewater treatment plants, collection networks and pumping stations, desalination plants, and more.[5]

In addition, severe limits on access and movement imposed by Israel and Egypt have hindered post-conflict repair and reconstruction. Israel has strong restrictions on a list of dual-use items that could be used for both civilian and military purposes. This list includes 23 essential items needed for the WASH sector, such as pumps, drilling equipment, and chemicals for water purification.[6] Egypt has kept the Rafah crossing into Gaza closed most of the time; in 2015 it was open only 32 days, in 2016, 44 days, and in the first nine months of 2017, it was open 28 days total.[7] After Operation Protective Edge the donor community gathered at the Cairo Conference on Palestine: Reconstructing Gaza, and pledged aid to rebuild Gaza. Although criticized,[8] the establishment of the Gaza Reconstruction Mechanism enabled the designation of massive investments for reconstruction of the civilian infrastructure. This mechanism has facilitated the entry of materials that otherwise would not have not been allowed in, and now most of the reconstruction of the water and sanitation facilities damaged in the conflict has been completed.[9]

At the same time, because of the inter-Palestinian rivalry between the Fatah-led Palestinian Authority (PA) and Hamas, the de facto government

in Gaza, the chronic electricity deficit in the Strip worsened in 2017. In the summer the PA announced that it would cut back its purchase of power for Gaza by $12 million per month, leaving the Strip with less than four hours of electricity per day.[10] Hamas and Egypt have agreed to import fuel from Egypt at a lower price than from Israel, but this piecemeal solution was unable to resolve the 18-20 hours of power outages experienced daily in Gaza. As a result, electricity for 186 facilities providing health, water and sanitation, and solid waste collection services has been generated with emergency fuel reserves delivered by the UN, which are not expected to last through the end of 2017.[11] The shortage of power and fuel to operate water and wastewater treatment facilities has further reduced Gaza's already limited access to clean water, exacerbating the health risks.

On October 12, 2017, the PA and Hamas signed a reconciliation agreement brokered by Egypt, and on November 1, Hamas began ceding control over the border crossings to PA hands.[12] As of the time of this writing, it is too early to estimate the impact of this change on Gaza's water and energy situation, but significant ease of access and movement in and out of Gaza is expected.

Limited Quantity and Quality

Access to safe drinking water in Gaza is extremely limited. In 2014, less than 11 percent of Gaza's population had access to safe drinking water through the public network, compared with almost 97 percent in the West Bank.[13] Access in Gaza has likely worsened since then, given the trends discussed below. As a result, 90 percent of the population depends on water tanks, bottles, and containers.[14] According to a 2016 report by the Palestinian Water Authority (PWA), the total water supply in Gaza for domestic use – including drinking, cooking, and bathing – amounted to 95.3 mcm in 2015, in comparison with 119.6 mcm in the West Bank.[15] Approximately half of Gaza's population receives water for domestic use for only 8 hours every 4 days; another third receives water for 8 hours every 2 days.[16] Limited water has led to a decline in both water consumption and hygiene standards.[17]

Gaza's readily accessible water supply has always been limited, but unsustainable demand and use has strongly affected water availability and quality. The coastal aquifer, located under the coastal plain of Israel and the Gaza Strip, is the only locally accessible source of freshwater in Gaza. Due to rapid population growth over the last decade, from nearly 1.5 million in

2007[18] to more than 2 million today,[19] water demand in the Gaza Strip has also rapidly increased. Given the lack of alternative water sources, this increase in demand has led to a rapid depletion of the aquifer, with water extraction rates more than three times the renewable supply.[20] This unsustainable rate represents a serious threat to the long term availability of the source, and according to UN reporting, it is expected to be irreversibly depleted by 2020.

Unsustainable depletion has also caused the groundwater table to fall below sea level, which in turn has degraded water quality. Seawater now infiltrates into the aquifer, and over the last decade salinity levels have risen well above World Health Organization (WHO) guidelines for safe drinking water (250 mg/l of chloride). In 2015, nearly all areas of the aquifer in Gaza were above this threshold, with many wells showing concentrations upwards of 1,000 mg/l.[21]

Aquifer water quality has also been degraded by nitrate contamination from untreated sewage. Recent data show that some 90 percent of the water extracted from the aquifer contains nitrate concentrations (NO_3) that exceed the 50 mg/l WHO limit.[22] Elevated chloride and nitrate levels in the Gaza Strip are particularly concentrated around population centers, including Gaza City, Deir al-Balah, and Rafah. A 2015 study found that only 3.6 percent of wells met WHO standards for both contaminants.[23]

As Gaza's limited water supply is not a new problem, purchased water has been a part of the supply mix for several decades. Israel's National Water Company, Mekorot, began selling water to Gaza in 1980, but this water has always represented only a small fraction of Gaza's total water use and need. In March 2015, faced with increasing risks connected to Gaza's water crisis, Israel committed to double the amount of water sold, from 5 to 10 mcm/year. However, due to limited storage capacity, Israel provided only 8 mcm until early 2017, when the German Development Bank (KFW) completed the refurbishment of the al-Muntar reservoir in Gaza City.[24]

In July 2017, the PA and Israel reached a new sales agreement whereby the PA would be able to buy 33 mcm of water per year from Israel, of which 10 mcm would be delivered to the Gaza Strip.[25] Based on the capacity of the existing pipelines, Israel could provide the first 5 mcm of water immediately. Further investments, however, are needed to build a new pipeline connecting Israel to Gaza to supply the remaining 5 mcm. Once the agreement will be fully implemented, Gaza will purchase a total amount of 20 mcm/year.

The imported water could be blended with groundwater, making 40 mcm of potable water available. Though an increase over previous agreements, this amount would still not meet water demand in Gaza.

The chronic shortage of safe water has led Gaza's residents to be increasingly dependent on small-scale desalination of brackish water by private vendors. Per a recent report, nine in ten people in Gaza drink desalinated water produced by 154 public and private desalination plants, only 48 of which are licensed and monitored.[26] Even if these small desalination plants reduce salinity, they do not necessarily remove pollutants effectively. In addition, the small desalination plants currently function at 15 percent of their capacity due to insufficient power supply.[27]

Scarcity has made water very expensive in the Gaza Strip, despite its low quality and inconsistent supply. According to UN standards for affordable water, the cost should not exceed 3 percent of household income.[28] However, according to a survey from 2010, some residents of Gaza spend as much as one third of their income on water, and 83 percent of households report they rely mainly on private vendors.[29] Moreover, households without the ability to pay must rely instead on unregulated wells.[30]

In the long run, solving Gaza's water woes will require large scale desalination. Plans for the construction of necessary desalination plants are under development, but such facilities cannot work without consistent power supply, which is now unavailable.[31]

Sewage Treatment: Only Partly Operational

Sewage infrastructure in Gaza is deficient.[32] In 2011, the sewage network covered only two thirds of Gaza's population and was then in a state of disrepair. The remaining third use cesspits and open drains to dispose of their wastewater. Since 2012 only 25 percent of wastewater collected has been treated and reused for irrigation.[33] The lack of adequate water sanitation stems from two main causes: delays in completion of three wastewater treatment facilities, and the lack of a reliable energy supply to operate such plants.

This problem too is not new. In the past, periodic cuts to the energy supply, often following direct Israel-Hamas confrontations, led to outages or malfunctions in the sanitation systems. In 2006, cuts to the fuel supply affected the operations of water pumping stations, as well as sewage treatment. Following Operation Cast Lead (2008-2009), the Gaza Coastal Municipal

Water Utility (CMWU) warned of the risks of an impending water and sanitation crisis in the Strip, including a growing danger of infectious disease outbreaks among the population.[34]

Today, the CMWU has only limited available power, which it uses to operate 55 sewage pumping stations and five partially operational wastewater treatment plants.[35] When the plants cannot treat incoming wastewater, the water is discharged into the Mediterranean instead. Currently, some 108,000 cubic meters of untreated or poorly treated sewage are discharged into the sea every day.[36] This pollution, according to reports, was the reason for the death of the five-year-old in July 2017 and for closure of the Ashkelon desalination plant in 2016. If present trends continue, the amount of sewage dumped into Gaza's sea might increase to 120,000 cubic meters per day.[37]

Grave Risks for Public Health

Poor water supply and quality, combined with insufficient wastewater treatment, have dangerous implications for public health in Gaza. The possible risk of disease transmission through waterborne pathogens is exacerbated by poor infrastructure and limited access to improved or clean water sources. Further, 51 percent of Gaza's population are children (age 0-17);[38] and research in other contexts has shown that young children are particularly vulnerable to waterborne disease.[39] Poor water quality and access contribute to an estimated 26 percent of all reported disease in Gaza.[40] Waterborne diseases are the primary cause of illness in children, particularly diarrheal diseases. These diseases have a further indirect effect on a child's ability to absorb nutritional content, leading to a higher incidence of childhood malnutrition.

As described below, water-related risks to public health stem primarily from two types of contamination – chemical and biological.

Chemical Contamination

Chemical contamination comes primarily from two sources: untreated or undertreated sewage, and run-off from fertilizer in agricultural areas. Because the water used by Gaza residents is largely untreated, chemical contaminants such as chloride and nitrate are often present in drinking water. These contaminants present risks to children, infants, and pregnant women, who are more susceptible to long term harm from greater exposure.[41] A secondary concern from an elevated presence of chloride in water is its

corrosive effects on metal pipes. In large enough concentrations, chloride will react with the metal ions to create soluble salts, which increase the levels of metals in drinking water.[42] Lead pipes can be similarly corroded with high levels of chloride to yield a higher concentration of lead in drinking water.[43] If current extraction and saltwater intrusion trends continue, the presence of chloride is expected to increase.

Nitrate contamination generally comes from wastewater or non-organic fertilizer infiltration into the groundwater supply.[44] Like chloride, nitrate poses the most significant health risks to infants under six months old. Consistent exposure by infants to high levels of nitrate can result in methemoglobinemia (blue baby syndrome), or an impaired ability to carry oxygen through the blood. Blue baby syndrome can lead to temporary digestive and respiratory problems, or in extreme instances to brain damage or death.[45] According to a 2000 Israeli study, elevated nitrate levels may also increase risk of hypertension in children.[46] In a 2008 study, samples of Gaza's drinking water showed that 90 percent contained nitrate in levels 2-8 times higher than the maximum for safe drinking water as determined by the WHO.[47] Half of the infants tested in this study showed signs of the disease, as well as diarrhea and high blood acid levels.[48]

One solution previously pursued to filter chloride and nitrate out of household water supplies along with other contaminants is the distribution and use of point-of-use (POU) reverse osmosis (RO) filtering units in Gaza. However, a 2011 UNICEF report found that 20,000 household RO units distributed to institutions and facilities that served children were not effectively filtering chemical and microbiological contaminants.[49] To operate at their rated capacity, these units need to be cleaned and disinfected, and some parts need to be replaced regularly. Without access to replacement parts or education on the importance of cleaning and disinfecting the units, the efficacy rate can decline significantly. This highlights the need for both better public health education and improved education about appropriate POU filter use alongside the general need for more filtration or other means of removing chemical contaminants from water.

Biological Contamination

Outbreaks of waterborne disease may affect large numbers of persons; they can spread particularly quickly in densely populated areas, especially in

individuals with compromised immune systems and inadequate sanitation infrastructure. Gaza is one of the most densely populated areas in the world and is particularly vulnerable to an outbreak of this type.[50] Due to a lack of wastewater treatment, Gaza is at imminent risk from an outbreak of waterborne disease.[51]

The most acute risks in Gaza are associated with ingestion of waterborne pathogens via water contaminated with feces from humans or animals. Fecal contamination can be a source of pathogenic bacteria (e.g., cholera, salmonella, shigella), viruses (e.g., enteroviruses including polio), and protozoa (e.g., giardia). Fecal contamination is most likely in areas where wastewater systems are poorly designed or maintained, and as a result, sewage can seep into drinking water from different points in the collection system.[52] Chances of microbiological contamination of water from the aquifer, particularly by fecal coliforms and fecal streptococcus, increase at each point in the water handling cycle.[53] Private vendors usually supply water through tanker cars at distribution points in non-hygienic conditions. Resulting contaminations lead to significant diarrheal and other water-related disease, not only in Gaza's infants (children under five) but also in the general population.[54]

In 2014 the Palestinian Ministry of Health published a report on communicable diseases in Gaza that identified several diseases transmitted through poor personal hygiene and insufficient public infrastructure, among them, acute hepatitis A, typhus, and acute diarrhea.[55] In the case of acute hepatitis A, the uneven geographic spread of the disease could possibly be explained by the variation of bad infrastructure in some governorates (districts) and varying levels of personal hygiene practices.[56]

Bacterial and Viral Pathogens

The risk of contamination in drinking water increases with each additional transfer point before reaching the user. For individuals in Gaza who are dependent on water tanks to deliver large quantities of drinking water, this means higher exposure rates to numerous coliform strains, fecal and otherwise, that can cause varying symptoms, including bloody diarrhea, stomach cramps, vomiting, fevers, and urinary tract infections. Children may risk greater exposure to bacterial contamination through water delivery and storage in schools.[57] Studies have found that total and fecal coliform strains

were present in higher numbers in samples from distribution networks as opposed to samples from wells or home-filtered water.[58]

The prevalence of bacterial contaminants in drinking water is of particular concern for children, given that UNICEF reported that water-associated diseases made up 26 percent of all childhood disease in Gaza and were the leading cause of childhood morbidity. Of these, 12 percent of deaths among young children and infants in 2009 were caused by diarrhea, an eminently treatable and preventable disease.[59]

Transmission of enteroviruses in populations with poor personal hygiene or untreated and polluted water can cause a variety of infections, some of which are mild or even symptomless. However, some strains of human enterovirus A and B species can have more serious effects, such as the spread of hand-foot-mouth disease or meningitis, respectively. Polio is perhaps the most well-known disease spread by enterovirus, both because of the severity of the symptoms associated with the disease and also its ability to spread quickly through large populations given the right conditions for transmission. While polio has largely been eradicated in the Gaza Strip thanks to proactive vaccination campaigns, meningitis is still one of the most common infectious diseases observed in children there.[60] Outbreaks are common and recently occurred in 1997, 2004, and 2013, dramatically raising the rate of infection among children and infants for brief periods in each instance.[61]

Giardia and Other Intestinal Parasites

As with coliform bacteria, water is more likely to be contaminated with parasites as it is transferred from the water distribution center to its eventual destination. Various intestinal parasitic agents (cryptosporidium, entamoeba histolytica, and giardia lamblia) are known to cause diarrhea in children, which is in turn associated with clinical diseases and higher mortality rates, as well as higher rates of malnutrition and possible developmental impairments in children.[62] In one study in Gaza, some 60 percent of kindergarten age children were found to suffer from at least one parasitic infection.[63]

Rates of intestinal parasites among Gaza's children may peak in agricultural areas and in neighborhoods with open sewage ponds.[64] A 2011 study found that children in Gaza were infected at high rates with both worms (helminths) and protozoa, and the younger children most vulnerable to worms were

not receiving deworming treatment typically administered to school-age children in classrooms.[65]

Public Health Risks in Israel and Egypt

These multiple, overlapping water and public health challenges may not remain contained within the Gaza Strip. The combination of poor water hygiene practices and insufficient sewage and water treatment in Gaza could lead to a disease outbreak that spreads outside of Gaza's borders. Viral pathogens like polio have the potential to travel through sewage and waterways outside of the Gaza Strip. Forms of both bacterial and viral pathogens can present a significant health risk not only to people living in the Gaza Strip, but also to Israeli and Egyptian populations, depending on how the pathogens enter communal water sources and whether outbreaks are caught early or allowed to spread. Indeed, polio has already been found in Israeli sewage systems, attributed to the sewage runoff from the Gaza Strip into Israeli waterways.[66]

The risk of a cholera outbreak has also been highlighted in recent years.[67] Cholera is an acute infection caused by ingestion of food or water contaminated with the bacterium vibrio cholera. Causative factors that contribute to cholera outbreaks are population density, mass gatherings, limited access to safe water, and poor sanitation – all conditions that exist in Gaza. Preventive measures, according to the WHO, include the development of piped water systems with water treatment facilities, water filtration, and disinfection of water, safe water storage, and construction of systems for safe sewage disposal.[68] All require long term investment and continued maintenance that are hampered due to reasons mentioned above.

Cholera affects both children and adults and can kill within hours if untreated. While health clinics in Gaza might be well-equipped for early detection of cholera, mitigation capacity is limited. Addressing a cholera epidemic in real time requires both a rapid response and treatment plan, which includes access to clean water, safe food, and hygiene practices in households, public places, refugee camps, and hospitals; neither of these is now viable in Gaza. To cope with the current electricity and water crises, hospitals have recently reduced cleaning and sterilization of medical facilities.[69] Gaza's hospitals operate on generators and any failure could jeopardize the ability of intensive care units to respond to an epidemic. An estimated 36

per cent of essential medicines – including antibiotics needed to reduce the duration of diarrhea associated with cholera – and 32 per cent of medical supplies are currently missing in Gaza.[70] In addition, the complex political situation and the lack of direct communication between all the parties involved could hinder any effective communication needed to deliver emergency aid, medicine, and electricity.

Although limited, movement of people and goods between Gaza and Israel, Egypt, and the rest of the world means that if cholera were to spread in Gaza, it would not remain confined to the Strip. Cholera outbreaks in Yemen in 2017 and in Iraq in 2015 demonstrate that given the circumstances, such a scenario is possible in the Middle East. To illustrate how easily viral and bacterial pathogens can spread in the right environment, one need only look at the example of the cholera epidemic in Haiti in 2010. Later found to have been spread by Nepalese peacekeepers living outside Port-au-Prince, cholera spread rapidly through the country and killed over 4,500 people in less than five months and eventually infected almost 300,000 others. The epidemic spread easily because the Haitian water and sewage infrastructure was devastated not long before by an earthquake, limiting access to clean drinking water and leaving Haitians to drink, wash, and bathe in river water contaminated by a strain of cholera from sewage flowing from the upstream peacekeepers' camp. Several critical lessons were learned from the Haitian experience, but chief among them was that the UN and the government of Haiti needed to prioritize long term investments in piped, treated drinking water and overall improvements in sanitation throughout the country. In addition, in the short to mid-term, the UN concluded that more emphasis was needed on community and household health programs teaching proper handwashing and hygiene practices, safe disposal of fecal waste, and low cost water purification techniques.

The risks that Gaza's water problem pose to Israel were first mentioned in the Israeli media in 2016 after the Ashkelon desalination plant, which supplies approximately 15-20 percent of Israel's water, was shut down for several days due to pollution from Gaza. More recently, however, in May 2017, the Israeli state comptroller issued a report that for the first time took on this issue and described water pollution as Israel's most serious cross-border environmental hazard. State Comptroller Joseph Shapira wrote that such widespread pollution not only damages the groundwater of Israel and

its neighbors, but also harms public health and quality of life. Noting that the government of Israel has yet to formulate a policy for transboundary environmental management with its neighbors, the report called upon the different authorities to join forces to reduce the contamination of resources shared by Israel and the Palestinians, mostly Gaza. The Environmental Protection Ministry welcomed the state comptroller's findings, stressing that "environmental issues do not consider boundaries created by man."[71]

Conclusion

Gaza's dire water, sanitation, and electricity challenges are complex and deeply intertwined. Even so, they could be addressed in the long term through greater investment in water and wastewater treatment infrastructure and new power infrastructure, along with greater water or electricity purchases from outside Gaza. These are all achievable with existing technologies.

Instead, the current barriers to a policy solution are largely political. The complex political dynamic in the region between Israel and Hamas, the intra-Palestinian rivalry between Hamas and the PA, and tension with Egypt make the situation extremely difficult. Reconciliation between the PA and Hamas may help alleviate some of the WASH (and energy) challenges, but effects of the process are too early to assess. While only long term political solutions could adequately address the core problems of water and sanitation in Gaza, it is important to take immediate actions within the existing political environment and constraints that will help ease the crisis and reduce the likelihood of a significant public health disaster. Among these are several ongoing efforts or possible expanded efforts by regional stakeholders or international donors:

a. *Purchased water*: The agreement that Israel and the Palestinians signed in 2017 on selling an additional 10 mcm of water to Gaza should be implemented quickly. The imported water could be blended with groundwater, making almost 40 mcm of potable water available. While 5 mcm of water could be provided immediately, a new pipeline from Israel to Gaza should be constructed to convey the additional supply.
b. *Clean water storage and pipeline system*: One of the limiting factors of the amount of water that can be sold to Gaza from Israel is the lack of storage capacity and the poor conditions of the existing pipeline system. Additional storage capacity and urgent investment in network losses

are necessary. Following the completed refurbishment of the al-Muntar reservoir by KFW, donors could be further encouraged to build an additional reservoir to accommodate water imported from Israel.

c. *Household disinfection or water treatment*: Chemicals for water treatment, spare parts for existing POU filters, and/or hygiene kits should be distributed to vulnerable households in Gaza. Even though these materials may be on Israel's dual-use list, this may be a necessary step to prevent outbreaks of waterborne disease in advance of a long term solution.
d. *Power supply for wastewater treatment*: In June 2016, Israel approved the supply of an additional 6 megawatts (MW) of electricity to Gaza, in order to power a new World Bank-led wastewater treatment plant in northern Gaza (the NGEST project). However, considering the state of the existing grid connection between Israel and Gaza and the inability to control the allocation of this additional electricity once it has crossed the border, without the construction of a dedicated power line that would connect the Israeli provider to the wastewater plant, this additional supply may be dispersed and not reach its final destination. The construction of this power line as an interim measure would allow for the efficient operation of the plant.
e. *Backup power and spare parts*: Donors could also secure fuel to operate backup electricity generators in hospitals and/or water and sanitation installations. Spare parts essential for maintenance of critical facilities would also be a key near term step.
f. *Regional taskforce*: Despite the political challenges, all relevant stakeholders, especially the PA, Israel, Egypt, and the international community should form a special taskforce that would prepare an action plan to implement immediate and mid-term responses to prevent a disease outbreak and contain it if such an outbreak occurs.

Notes

This paper is adapted from a RAND Corporation research report: Shira Efron and Jordan R. Fischbach et al., "Gaza's Water and Sanitation Crisis and its Implications for Public Health," forthcoming.

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